SUSY at LHC now and future

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SUSY after LHC

- Checking current excess (ATLAS 1l+ missing +jets

  Han,Nojiri, **Takeuchi,** Yanagida (arXiv tomorrow…)

- Future: various direction…
  - ex : application of quark gluon separation to get max sensitivity

  Bhattacherjee, Mukhopadhyay, Nojiri, **Sakaki**, Webber arXiv Today 1609.08781

SUSY at LHC Now

current excess (stop channel)

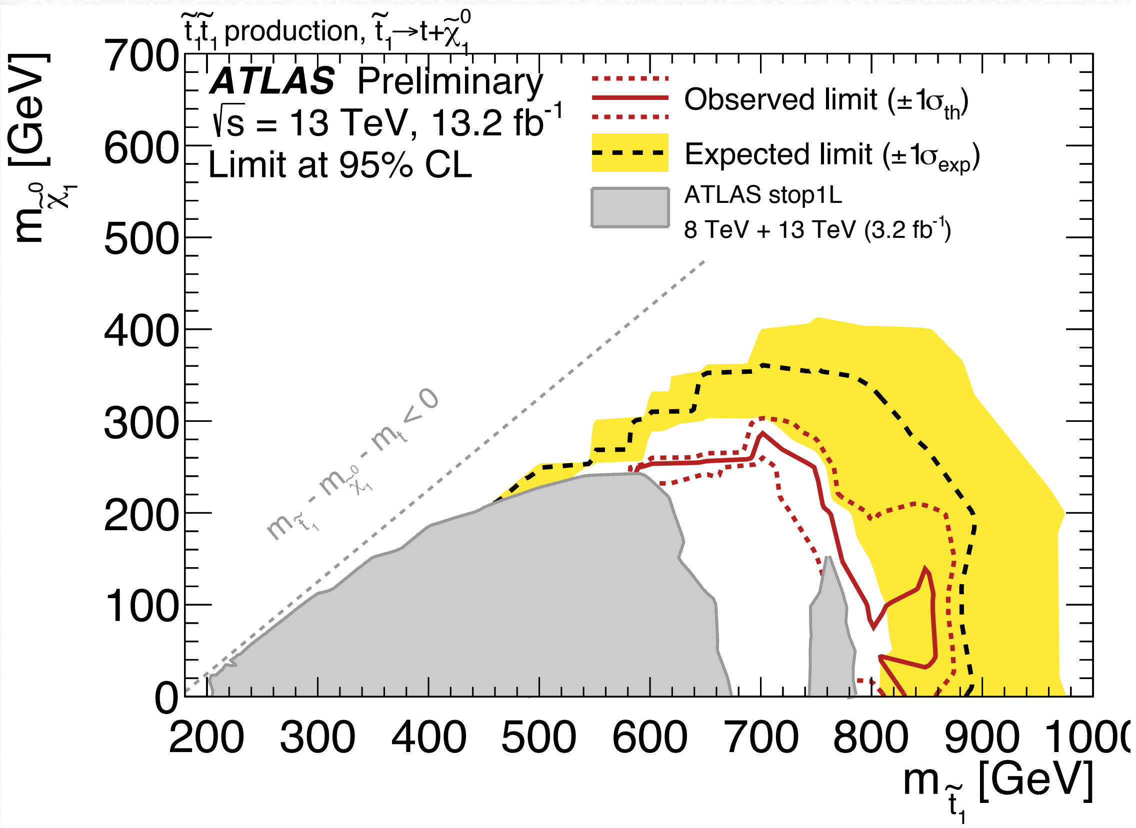
- ATLAS 1l + missing + jets

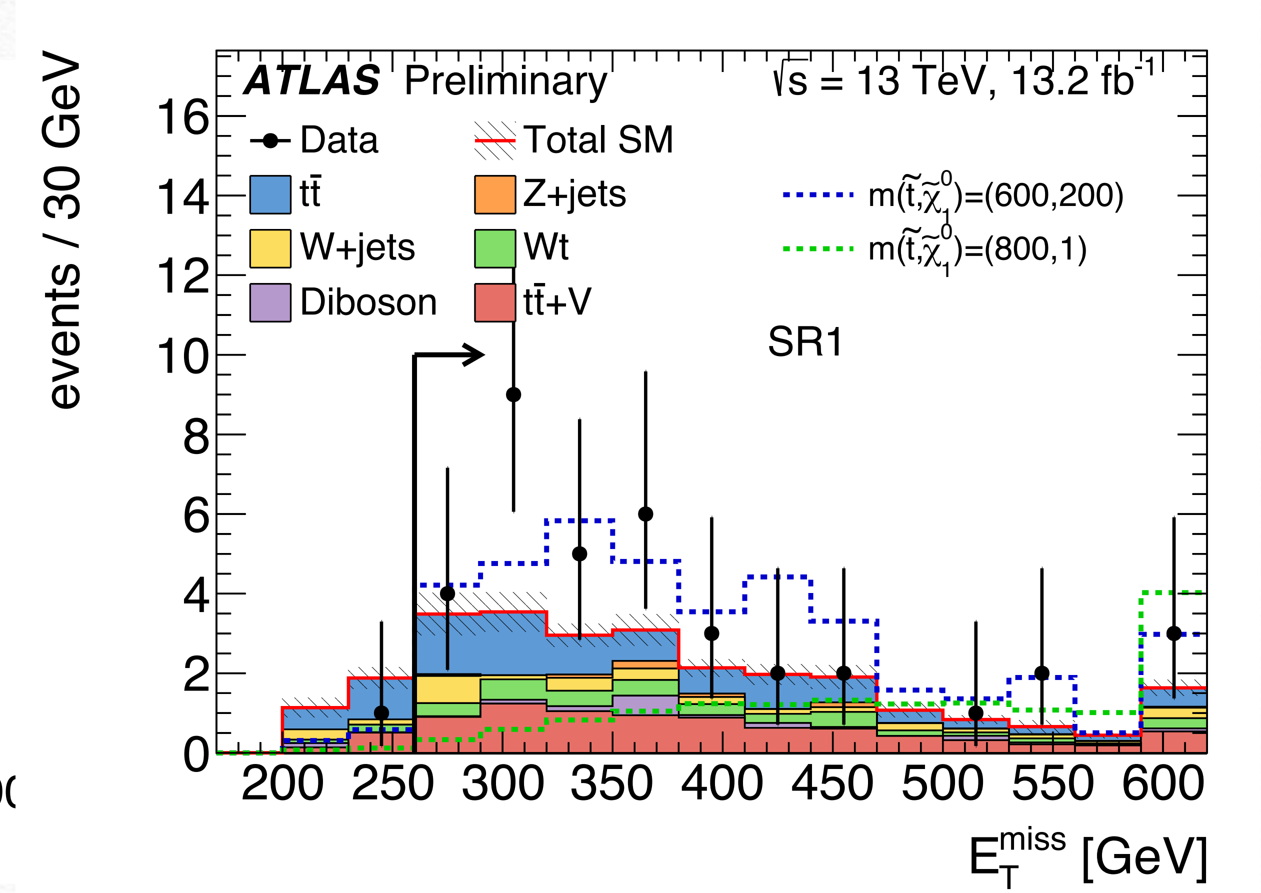
Signal region	SR1	tN_high	bC2x_diag	bC2x_med	bCbv	DM_low	DM_high
(n_j, n_b)	$(\geq 4, \geq 1)$	$(\geq 4, \geq 1)$	$(\geq 4, \geq 2)$	$(\geq 4, \geq 2)$	$(\geq 2, = 0)$	$(\geq 4, \geq 1)$	$(\geq 4, \geq 1)$
$\not{E}_T$ [GeV]	260	450	230	210	360	300	330
m_T [GeV]	170	210	170	140	200	120	220
am_{T2} [GeV]	175	175	170	210	-	140	170
Total background	24 ± 3	3.8 ± 0.8	22 ± 3	13 ± 2	7.8 ± 1.8	17 ± 2	15 ± 2
Observed	37	5	37	14	7	35	21
$p_0(\sigma)$	0.012(2.2)	0.26(0.6)	0.004(2.6)	0.40(0.3)	0.50(0)	0.0004(3.3)	0.09(1.3)
$N_{\rm obs.}^{\rm limit}$(95% CL)	26.0	7.2	27.5	9.9	7.2	28.3	15.6

TABLE I: Summary of some of the selection cuts and the results of the seven signal regions defined in ATLAS stop $\ell + jets + \not{E}_T^{miss}$ channel.

excess in various channel though all correlated (stop?)

Some distribution





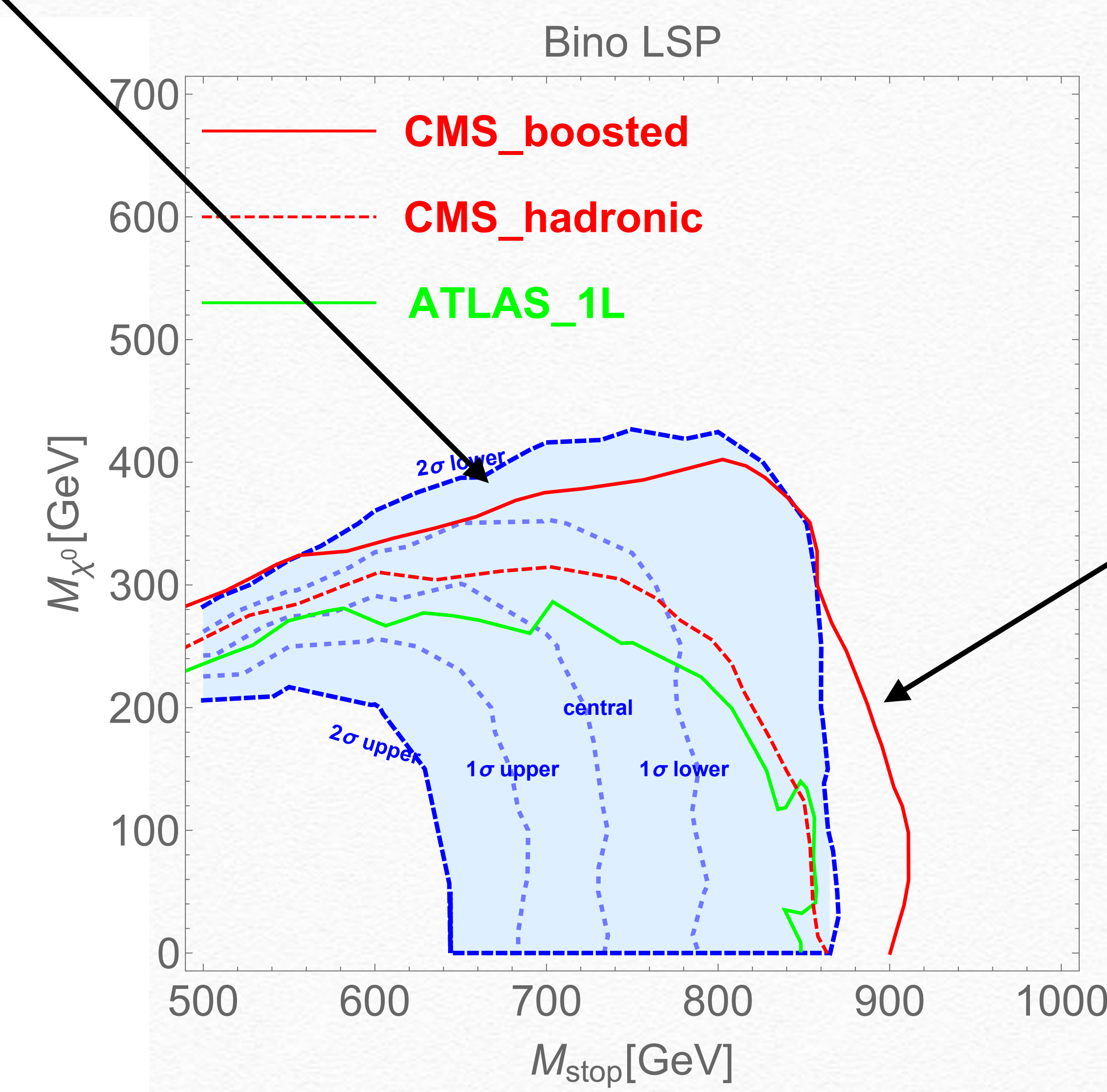
- Assume top partner decay into LPS and top
- Not happy because it is analyzed by simplified model (Kinematics are taken care of, but assume 100% branching ratio to draw contours)

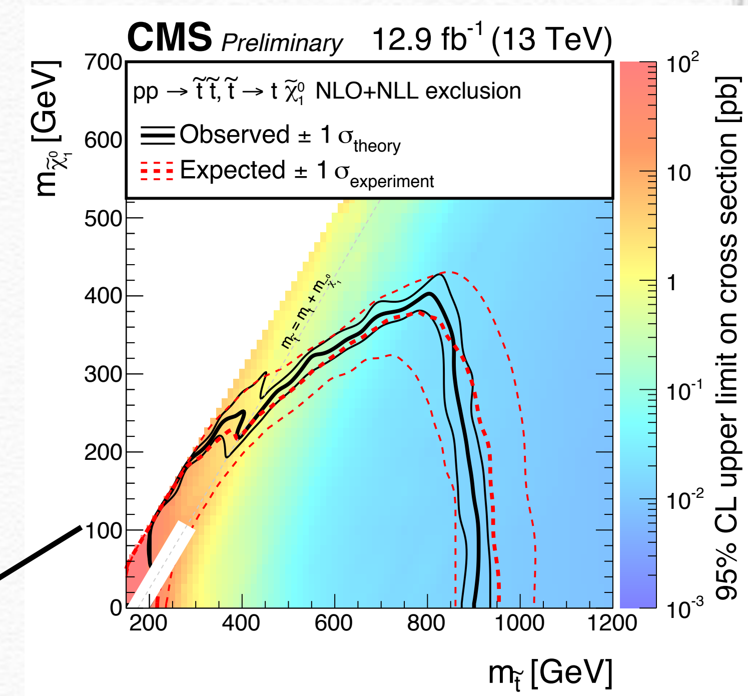
Why simplified model do not capturing the case

Han,Nojiri, Takeuchi, Yanagida(arXiv tomorrow or next week)

stop_R→Bino LSP case is almost exclude by CMS boosted top search :-(

marginal possibility in degenerate region

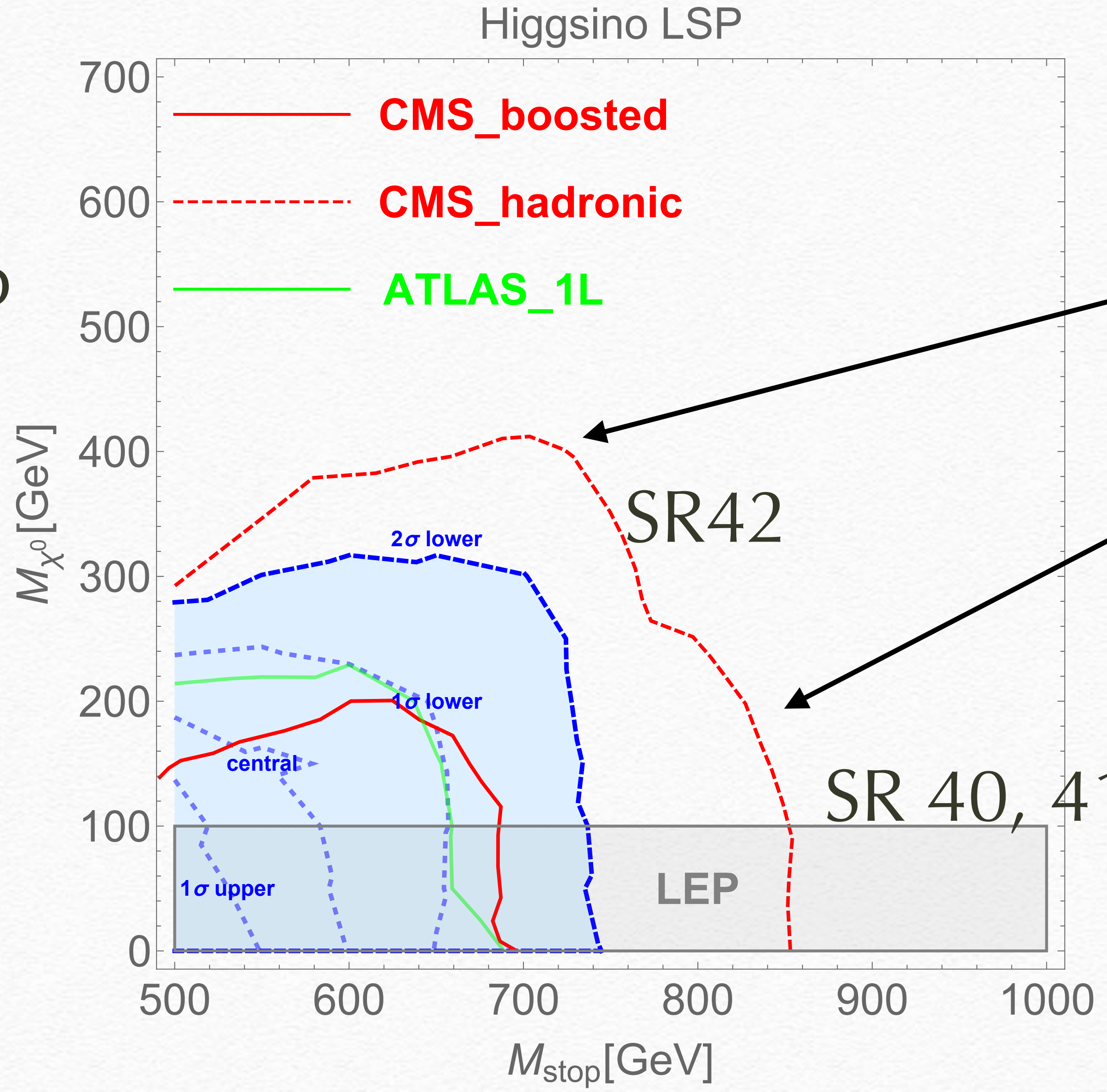




How about light Higgsino?

even worse? :-(CMS PAS SUS-16-029

50% t 50 %b



channels less than expected

SR42

SR 40, 41

SR 40,41 2 b jet ETmiss and b is not consistent with t
Nj=5~7, not boosted top and W, ETmiss> 450

Note: channels more than expected and channels less than expected tend to overlap

more complicated decay pattern

Need to

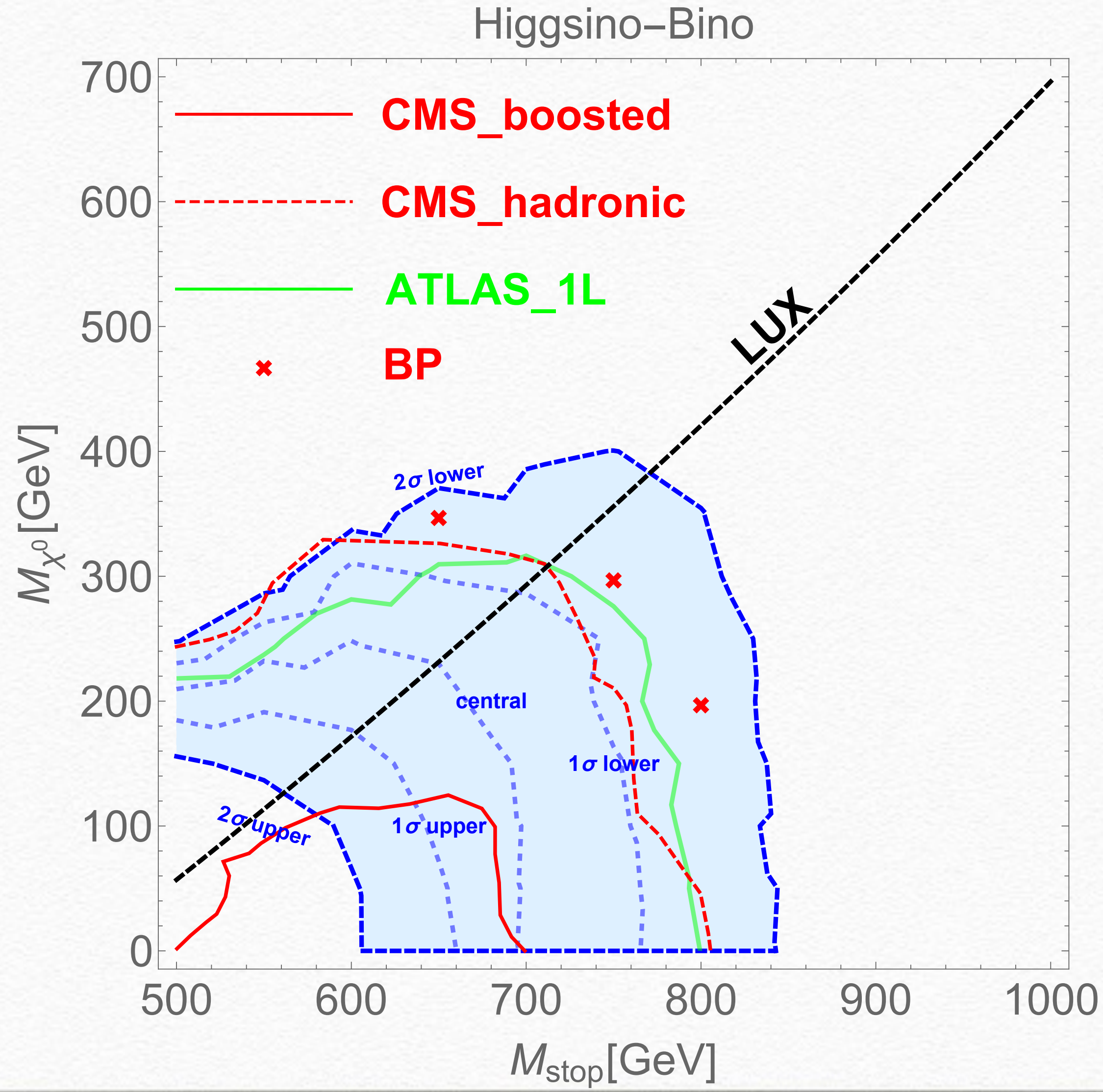
1. Reduce branch into stop to t chi

2. Keep lepton branch

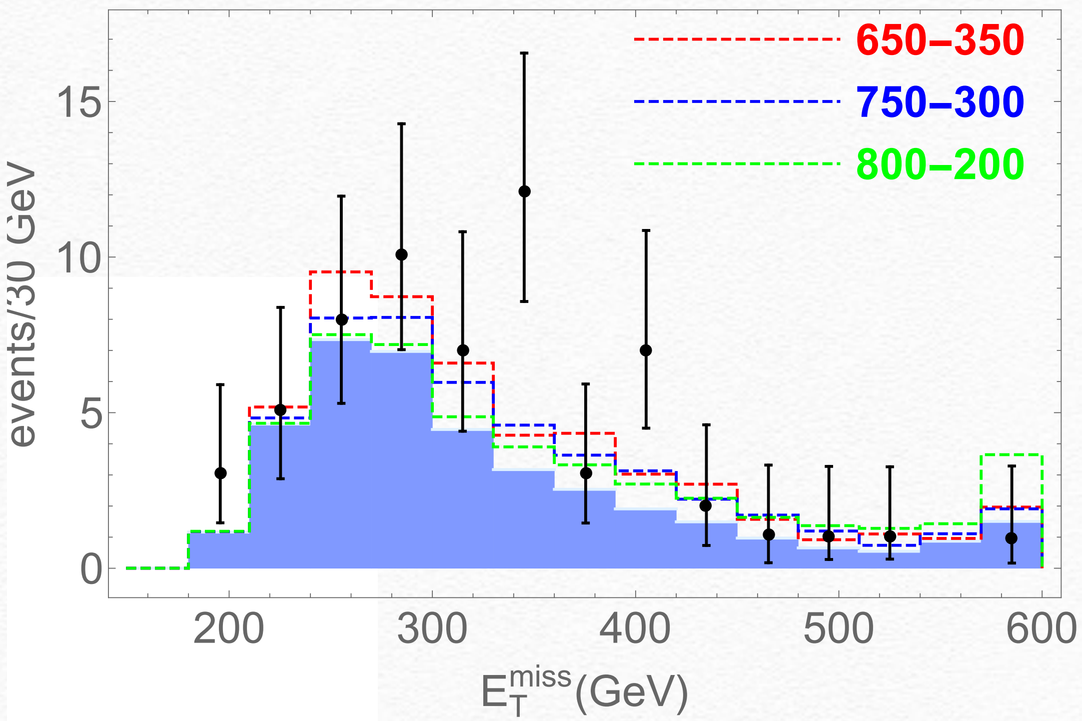
stop(right handed) →higgsino→ bino W .

*dark matter search constraint from Higgsino Bino mixing

*Dark matter density can be adjusted by bin-slepton co-annihiliation



distribution is not sexy but OK



bottom line:
We need to wait

SUSY at LHC
Future

BSM search in Future

- High Luminosity is possible but No large energy increase for a moment.
- Significance is expressed at $S/\sqrt{(B + (\delta B)^2)}$ where δB is systematical error of the background
    - clean channel extend with luminosity. → Theoretical error will reduce drastically at NNLO
    - New method which can reduce background might also be useful.

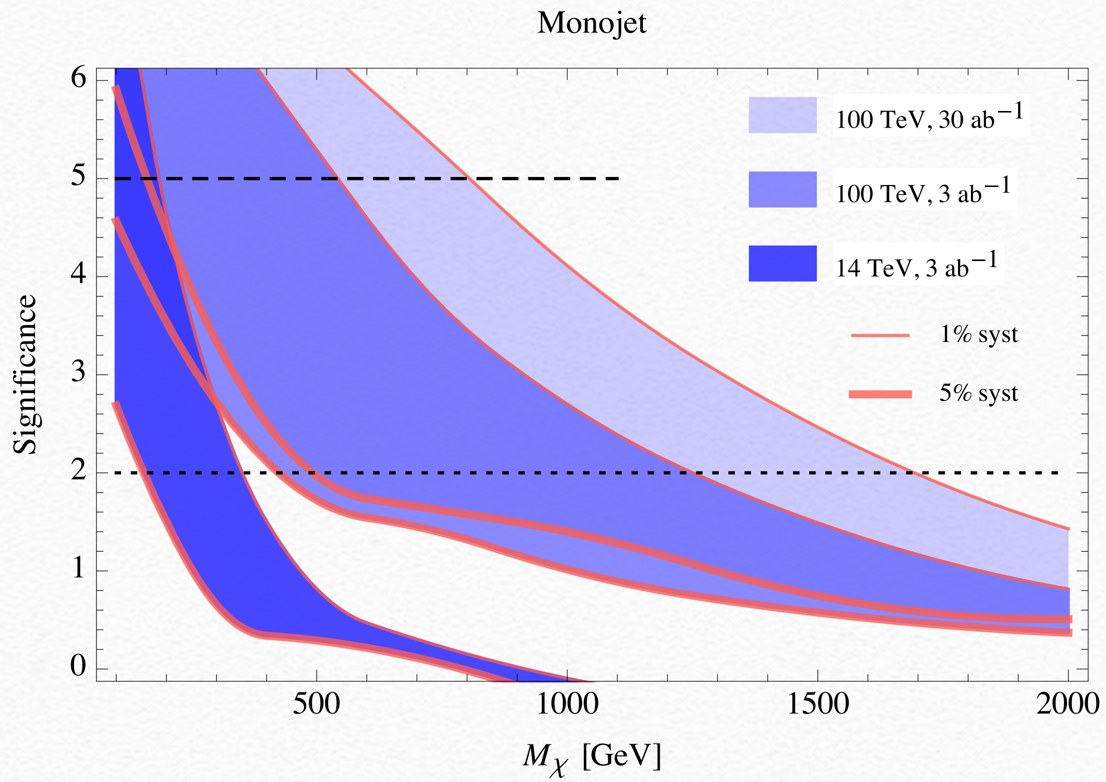


Figure 2. Reach of monojet searches.

Cirelli et al '14

I am going to talk about application of quark/gluon separation

What we may expect
ex： gluino→ qq X

- quark and gluon initiated jet are different: In parton shower, quark split into hard quark and soft gluon and gluon split into two gluon more equally.

- ME level pp-> gluino gluino-> 4q +missing: background Z+jets more gluons.

Process	$f_q^{j_1}$	$f_q^{j_2}$	$f_q^{j_3}$	$f_q^{j_4}$
$\tilde{g}\tilde{g}$+jets	0.92	0.87	0.77	0.64
Z+jets	0.64	0.55	0.27	0.16

contamination of ISR especially compressed spectrum

background also contains quark especially for the first jet.

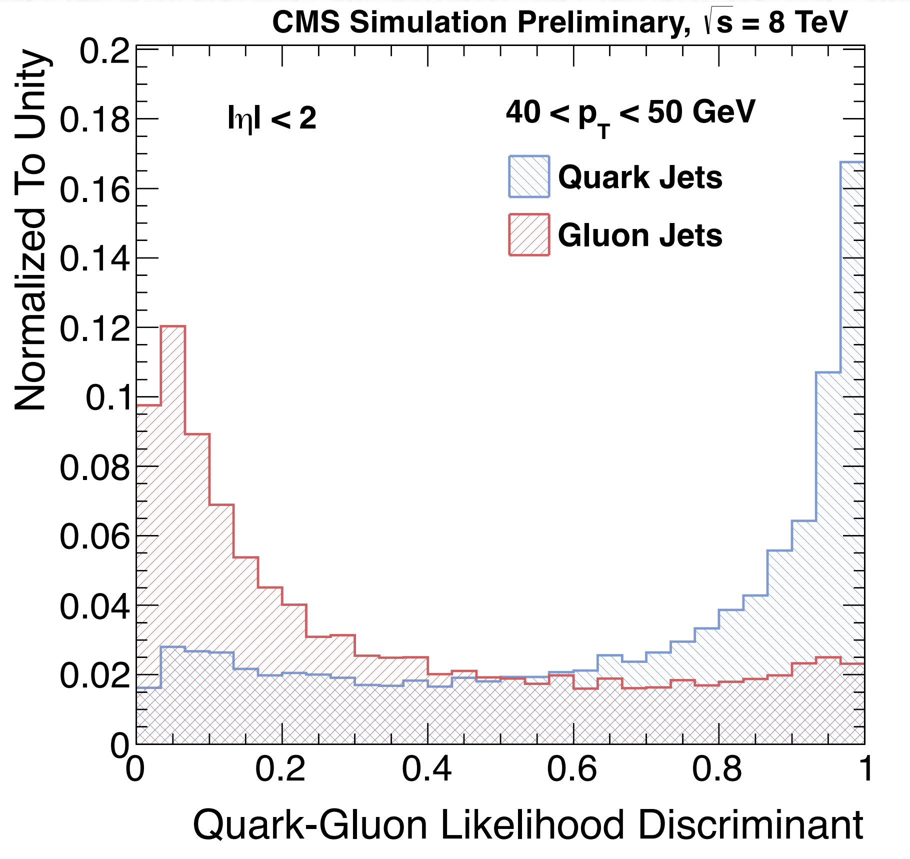
(Mgluino, Mchi) =(1750 GeV,750GeV) Meff> 1.8TeV

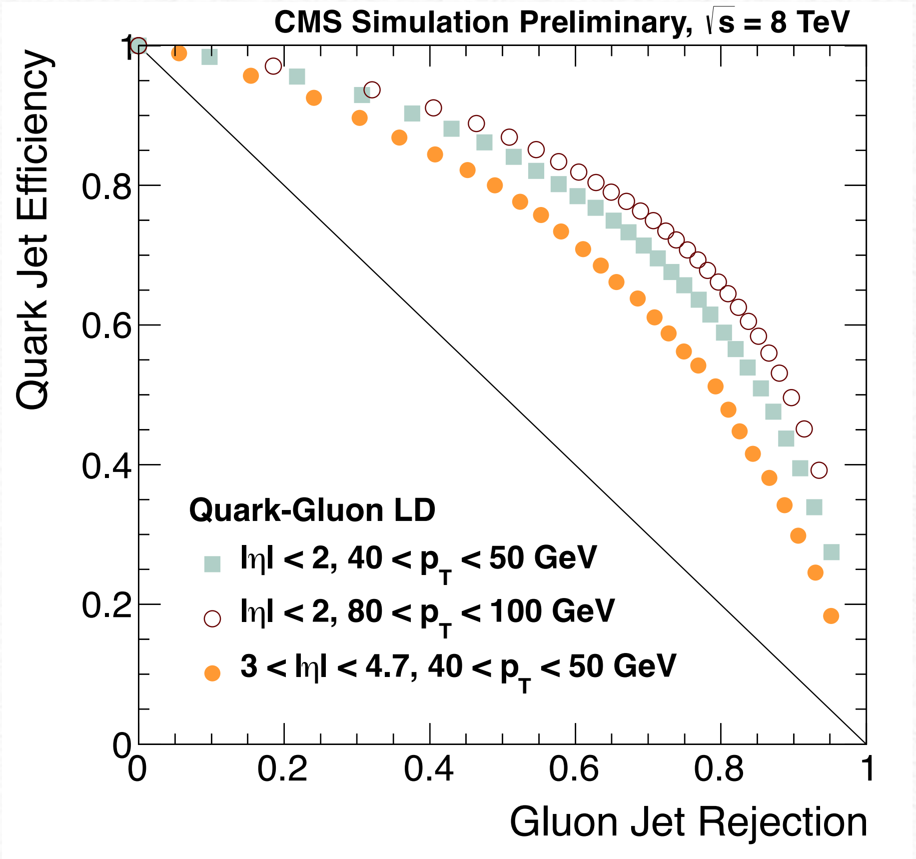
(we have checked Matrix level ISR generation is not necessary for this level of compressed spectrum

(Fraction is calculated following parton shower history)

experimental data

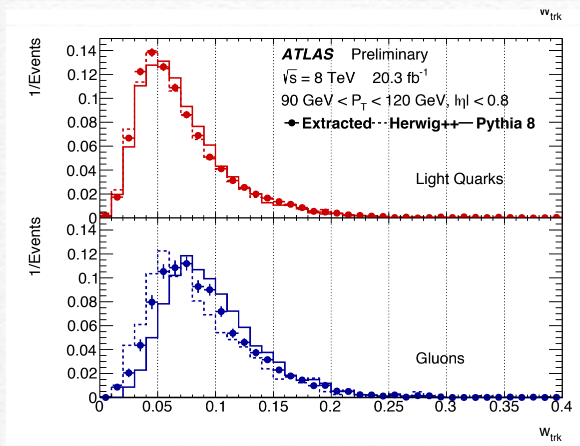
- recent experimental study in data driven approach.
  - γ j or Z j: jet is more likely to be quark
  - 2j event: Low pt: dominated by gluon jet, High pt quark and gluon jet





Discriminant (BDT score)

What is discriminant



re-sum needed

$$C_\beta = \frac{\sum_{i,j\in\text{jet}} E_{T,i} E_{T,j} (\Delta R_{i,j})^\beta}{\left(\sum_{i\in\text{jet}} E_{T,i}\right)^2}$$

soft physics

$$n_{\text{trk}} = \sum_{\text{trk}\in\text{jet}}$$

$$w_{\text{calo}} = \frac{\sum_{\text{const}\in\text{jet}} p_{T,\text{const}} \Delta R_{\text{const,jet}}}{\sum_{\text{const}\in\text{jet}} p_{T,\text{const}}}$$

....

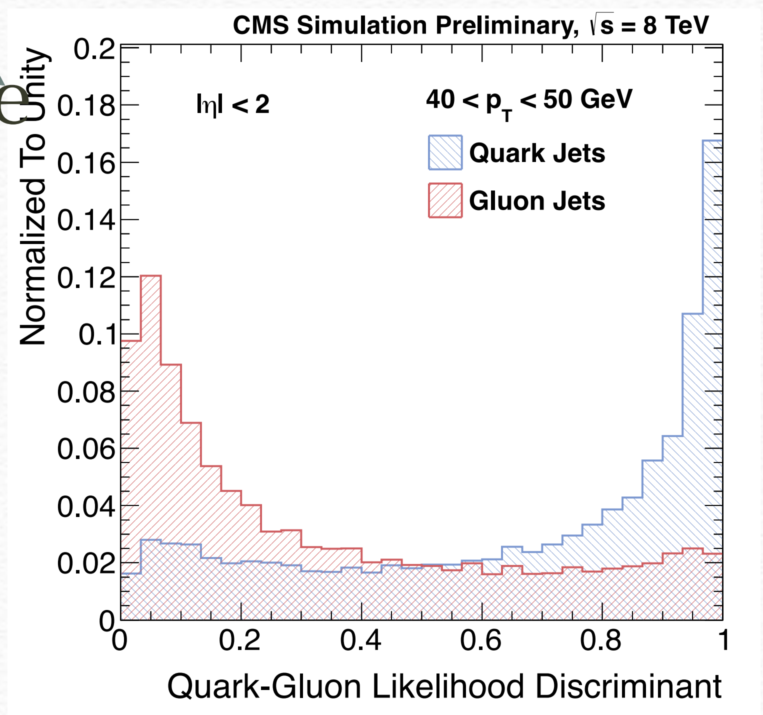
$$w_{\text{trk}} = \frac{\sum_{\text{trk}\in\text{jet}} p_{T,\text{trk}} \Delta R_{\text{trk,jet}}}{\sum_{\text{trk}\in\text{jet}} p_{T,\text{trk}}}$$

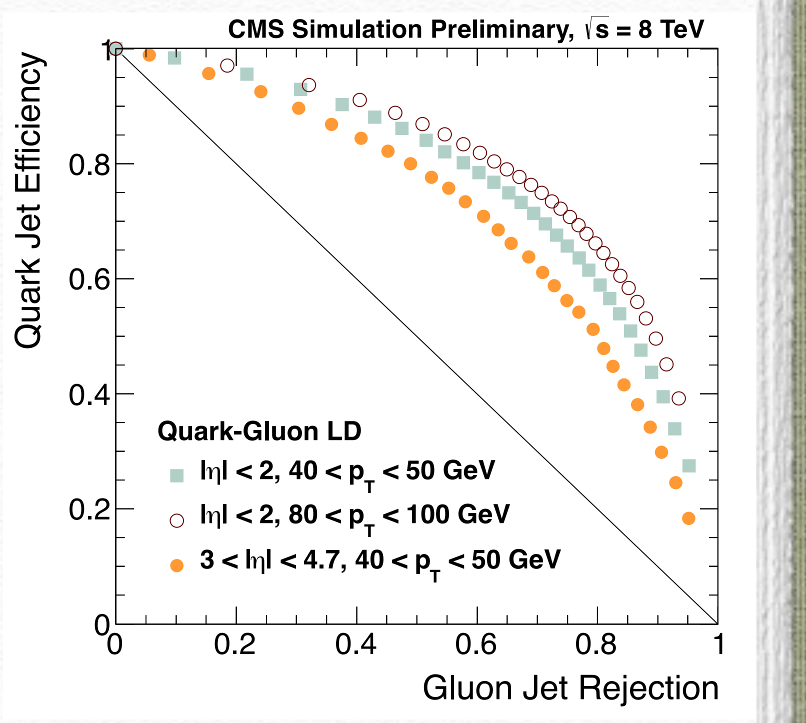
experimentally different

ROC

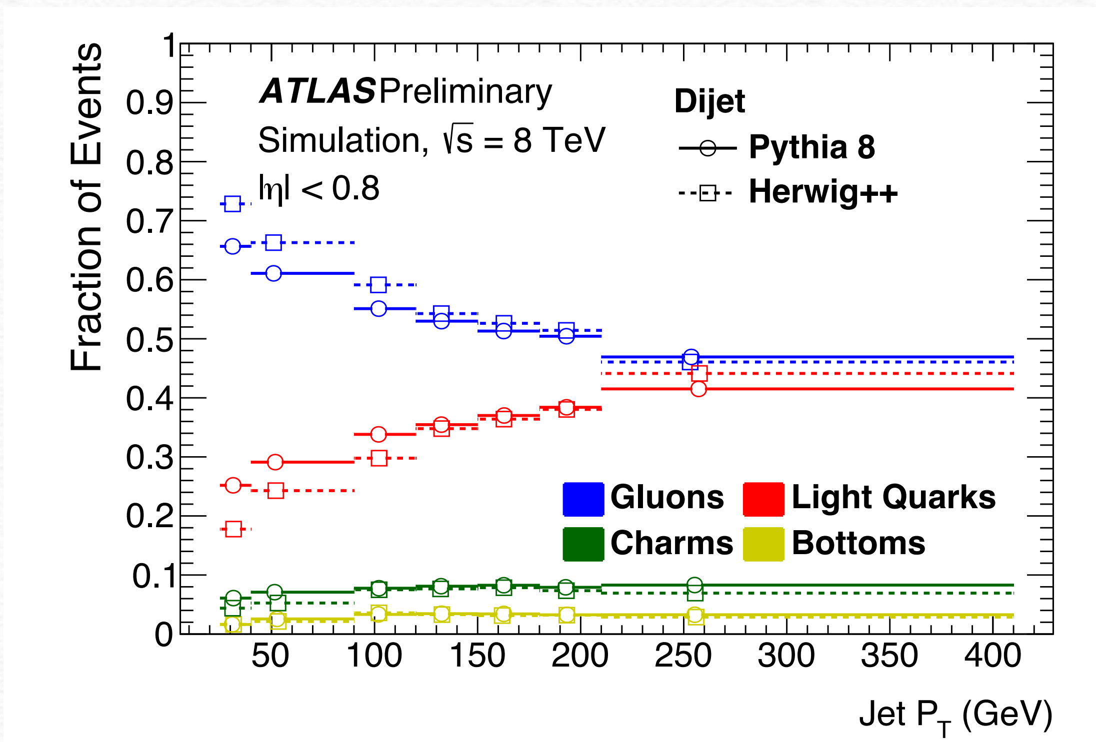
build a function which give gluon jet ~0 an quark~1

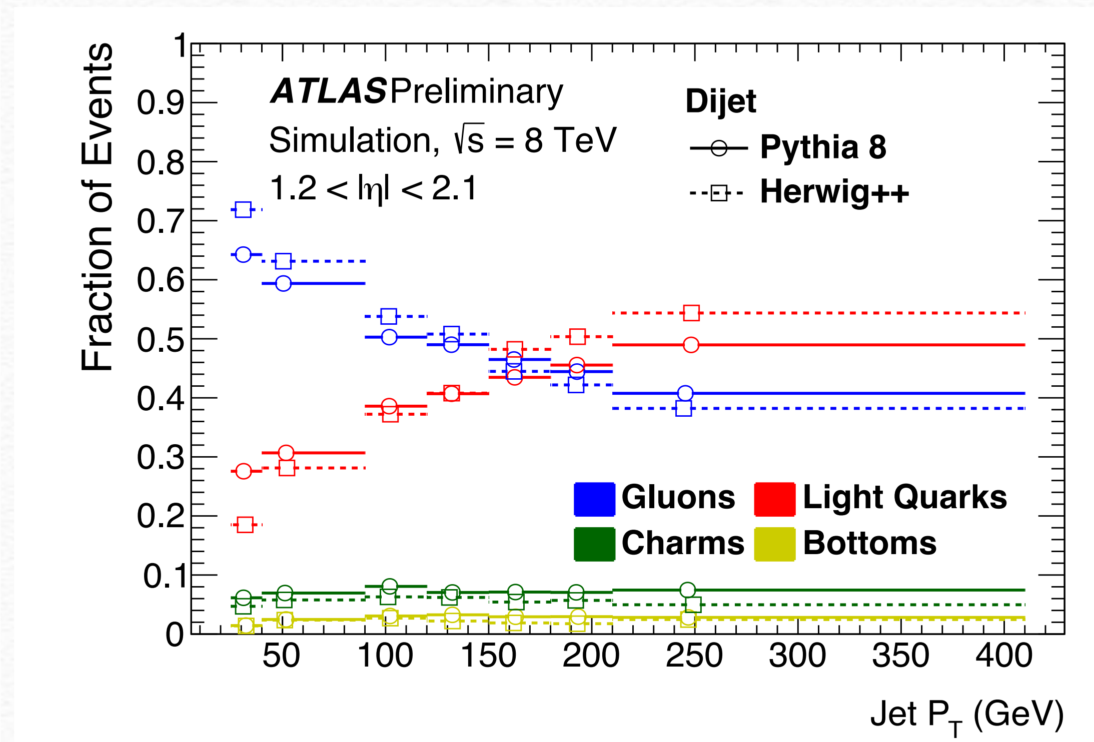
This function depend on method you use to build the function

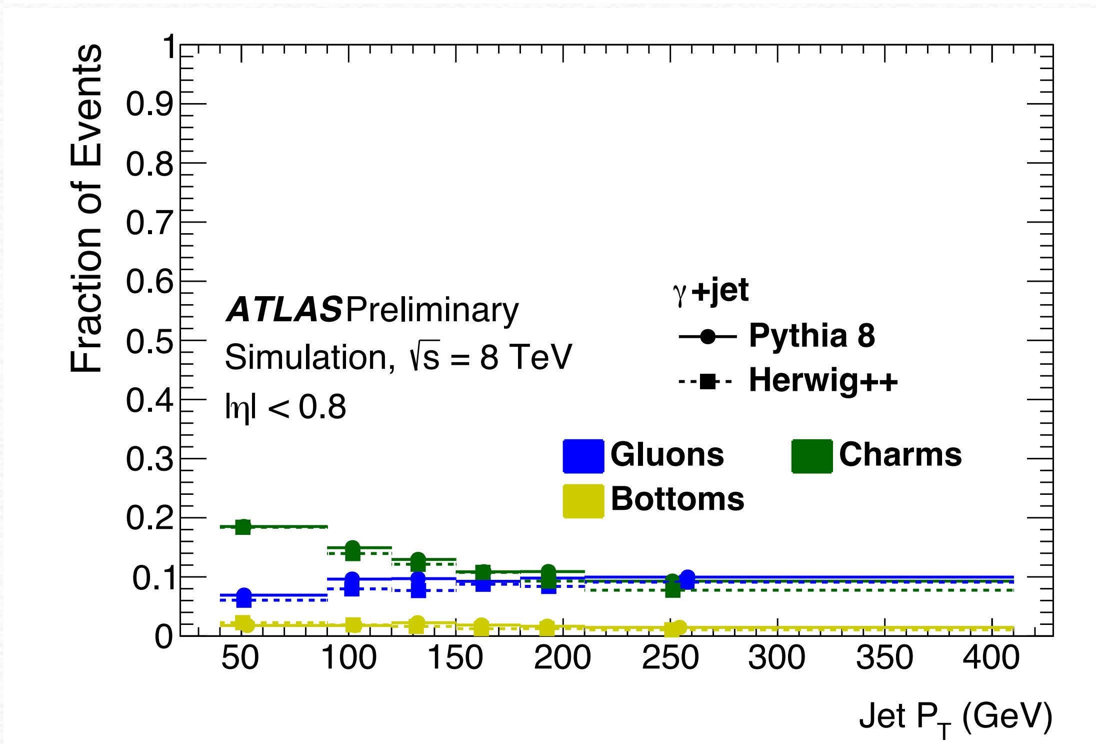


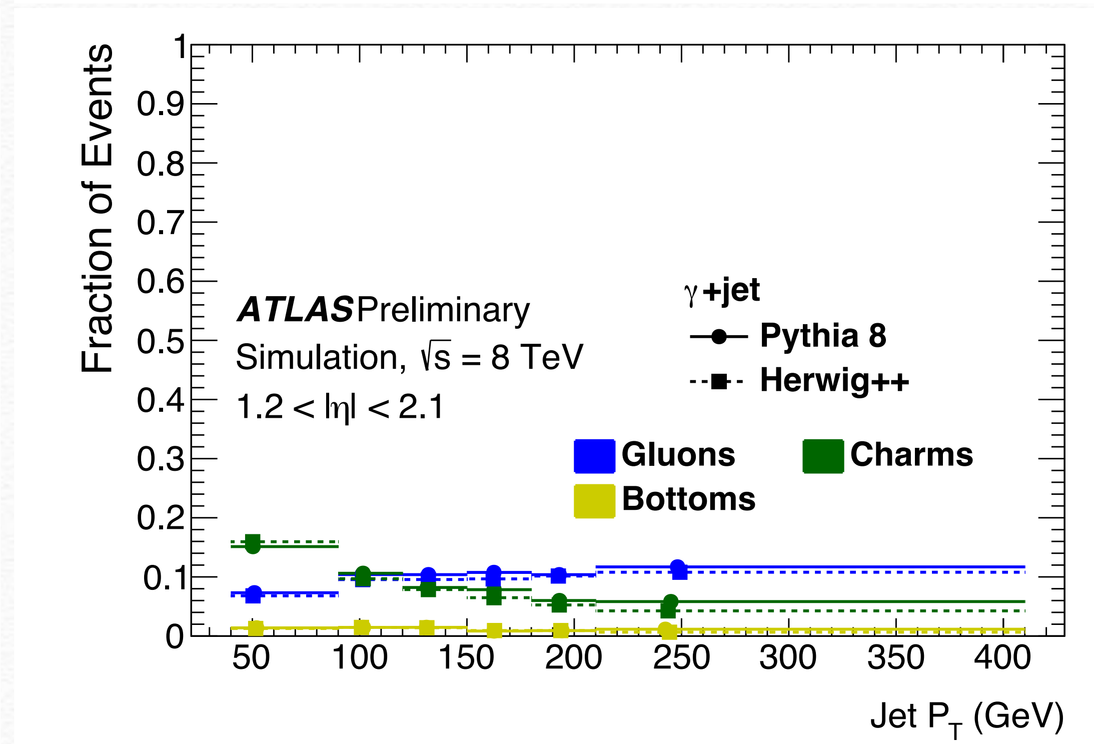


Fraction of quark gluon jet in MC









distribution of basic parameter (Pythia8 and Herwig++) compared with dat

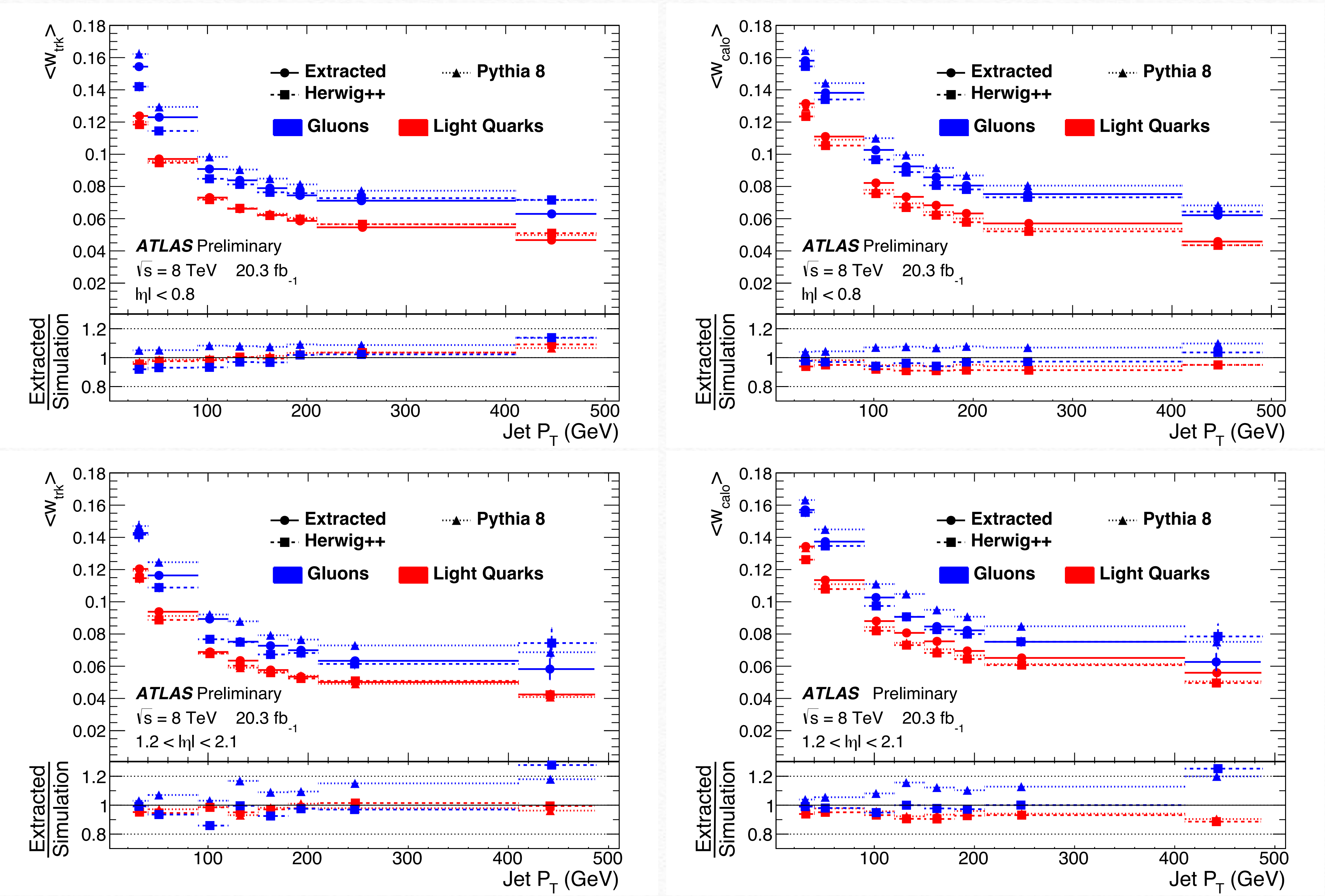


Figure 5: Means of extracted templates for w_{trk} (left) and w_{calo} (right) comparing data (solid line), Pythia (dotted line) and Herwig++ (dashed line). The top plots show the distribution for $|\eta| < 0.8$, the bottom plots are for $1.2 < |\eta| < 2.1$. The bottom panel of each plot shows the ratio of the Pythia and Herwig++ distributions to the extracted templates. The last p_{T} bin in all plots includes overflow events.

consistency among the sample (note agreement of av is not enough)

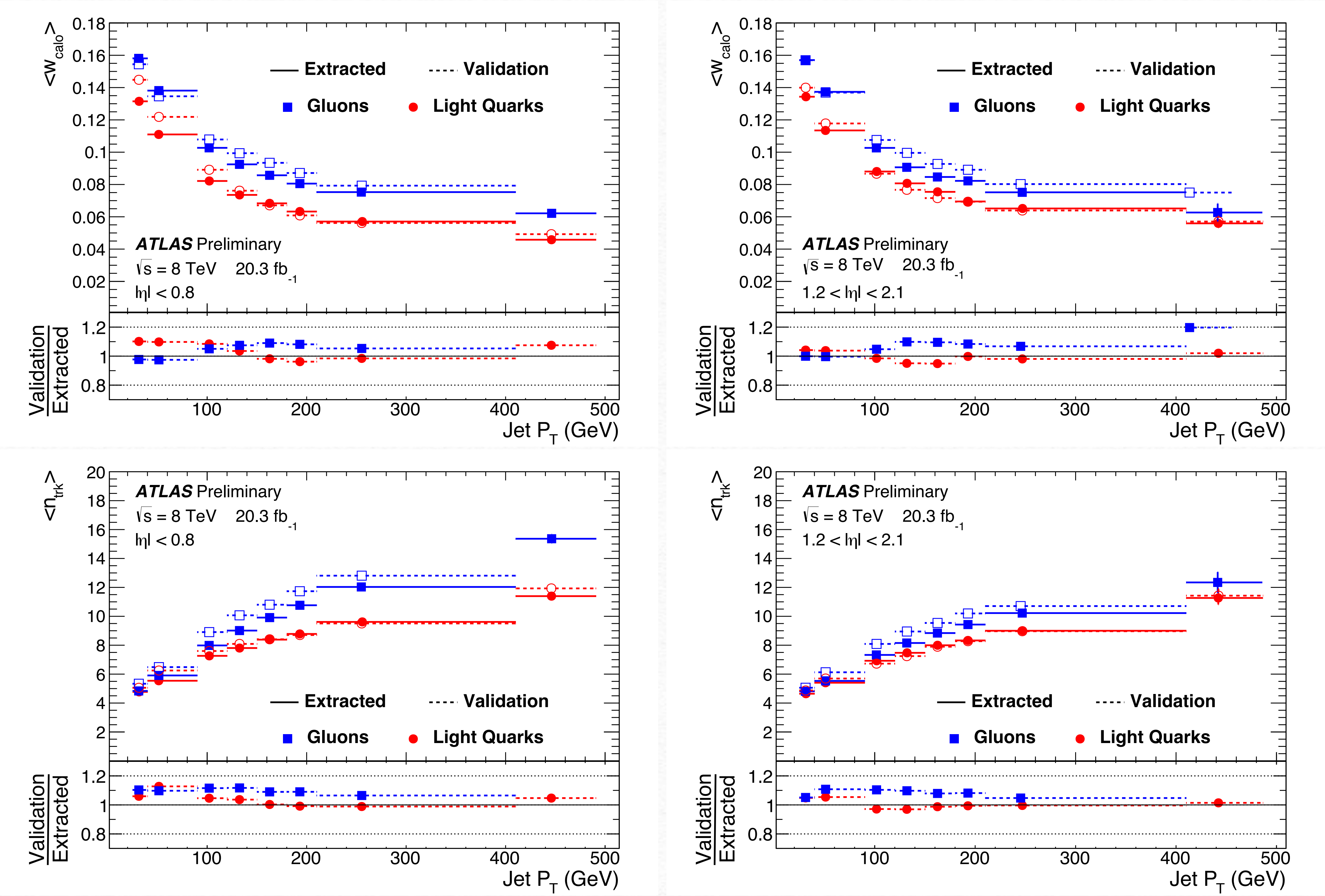


Figure 7: Comparison between the means of discriminating variables as a function of p_T. Templates were extracted using dijet and Z+jet samples in 25 GeV$< p_T <$ 40 GeV, all three samples in 40 GeV$< p_T <$ 90 GeV and dijet and γ+jet samples for $p_T >$ 90 GeV. The leading jet has $|\eta| < 0.8$ (left) or $1.2 < |\eta| < 2.1$ (right). The last p_T bin in all plots includes overflow events.

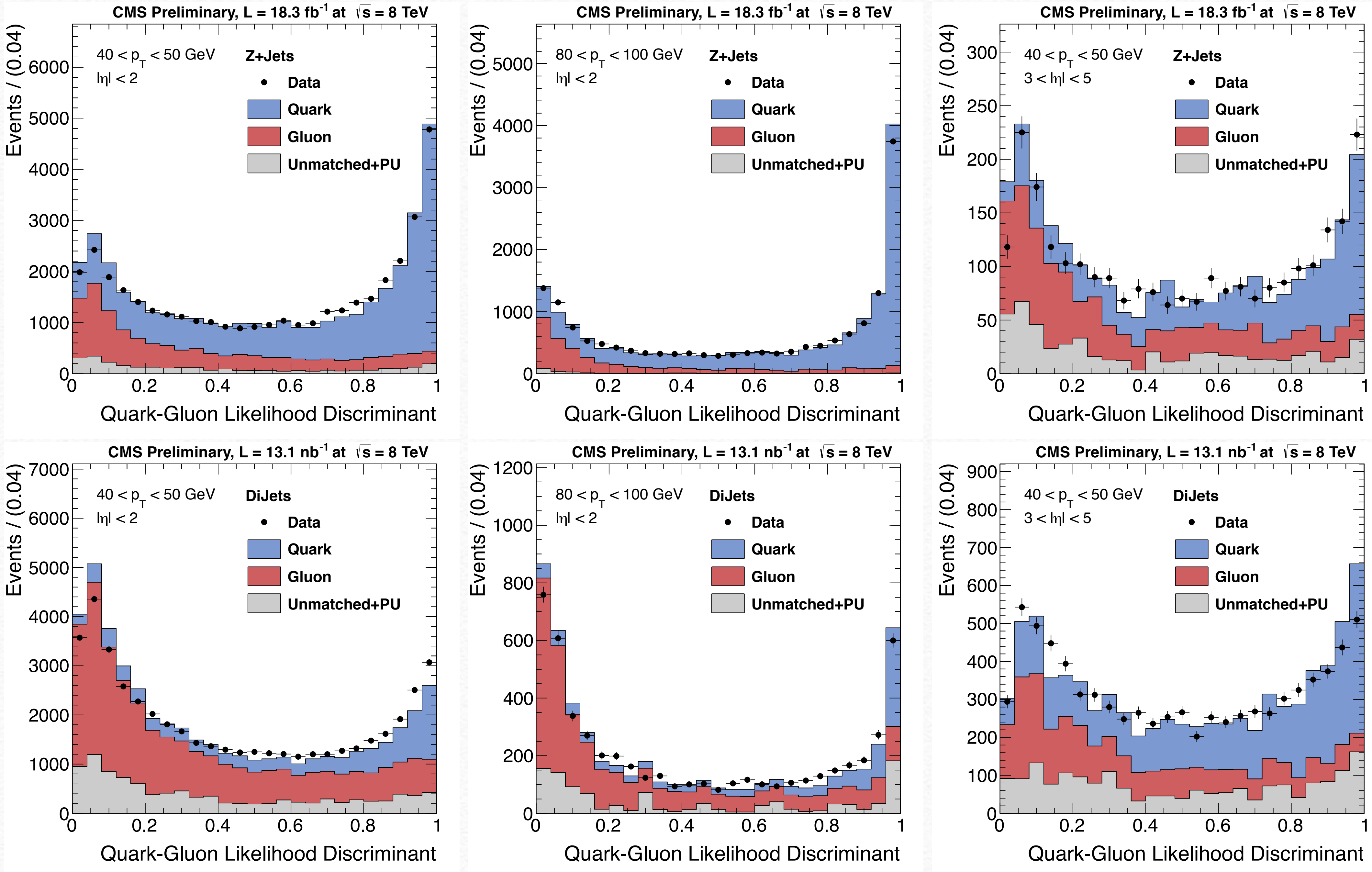


Figure 3: Data-MC comparison for the quark-gluon discriminant in Z+jets (top) and dijet (bottom) events for jets in the central region ($40 < p_T < 50$ GeV to the left, $80 < p_T < 100$ GeV in the center) and in the forward region with $40 < p_T < 50$ GeV (right). The data (black markers) are compared to the MADGRAPH/PYTHIA simulation, on which the different components are shown: quarks (blue), gluon (red) and unmatched/pileup (grey).

Checking if this is useful for BSM (gluino search)

Bhattacherjee, Mukhopadhyay, Nojiri, Sakaki, Webber

Z+q and Z+g
(instead of di-jet)

Delphes3

pT dependent
profile of C1, mj/pT, nch)

ROOT, TMVA(BDT)

B(C1, mj/pt,nch, pT)

2 gluino -> 4j +missing
Z+3j (not Z+4j matched)

Delphes3 & B

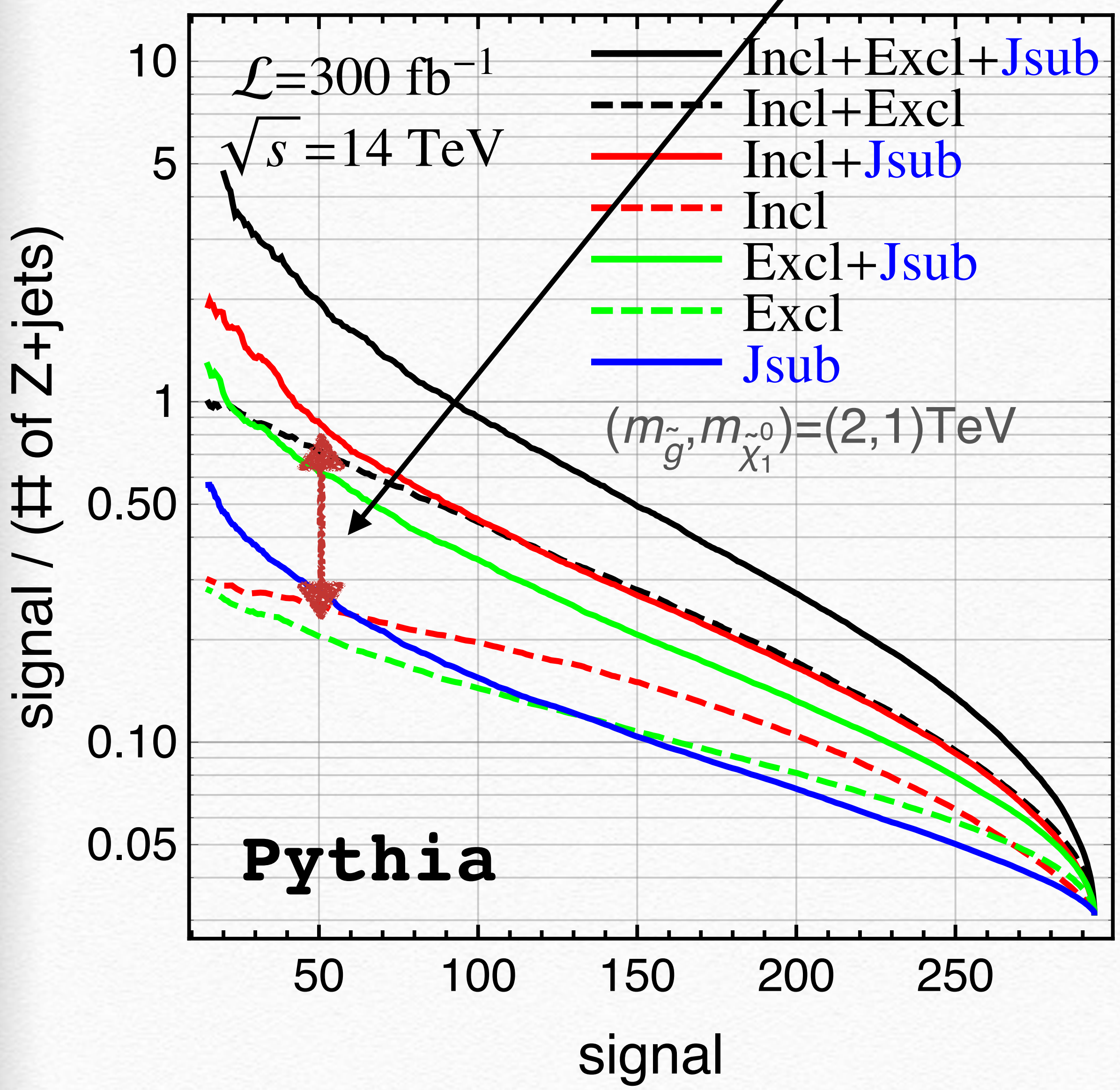
TMVA with
ETmiss, Meff
pT,B up to 4th jet
(4th jet is PS)

use ROC to find bast
S/sqrt(B+(delB)^2)

scale Z+3j to reproduce
13TeV total background
(Z+jets, W+jets, tt)

ROC curve(gluino 2TeV LSP 1TeV)

Gain by quark gluon separation: No new kinematical cut
(no new systematics by reducing phase space out)
factor 3 gain over background



Worse in Herwig++

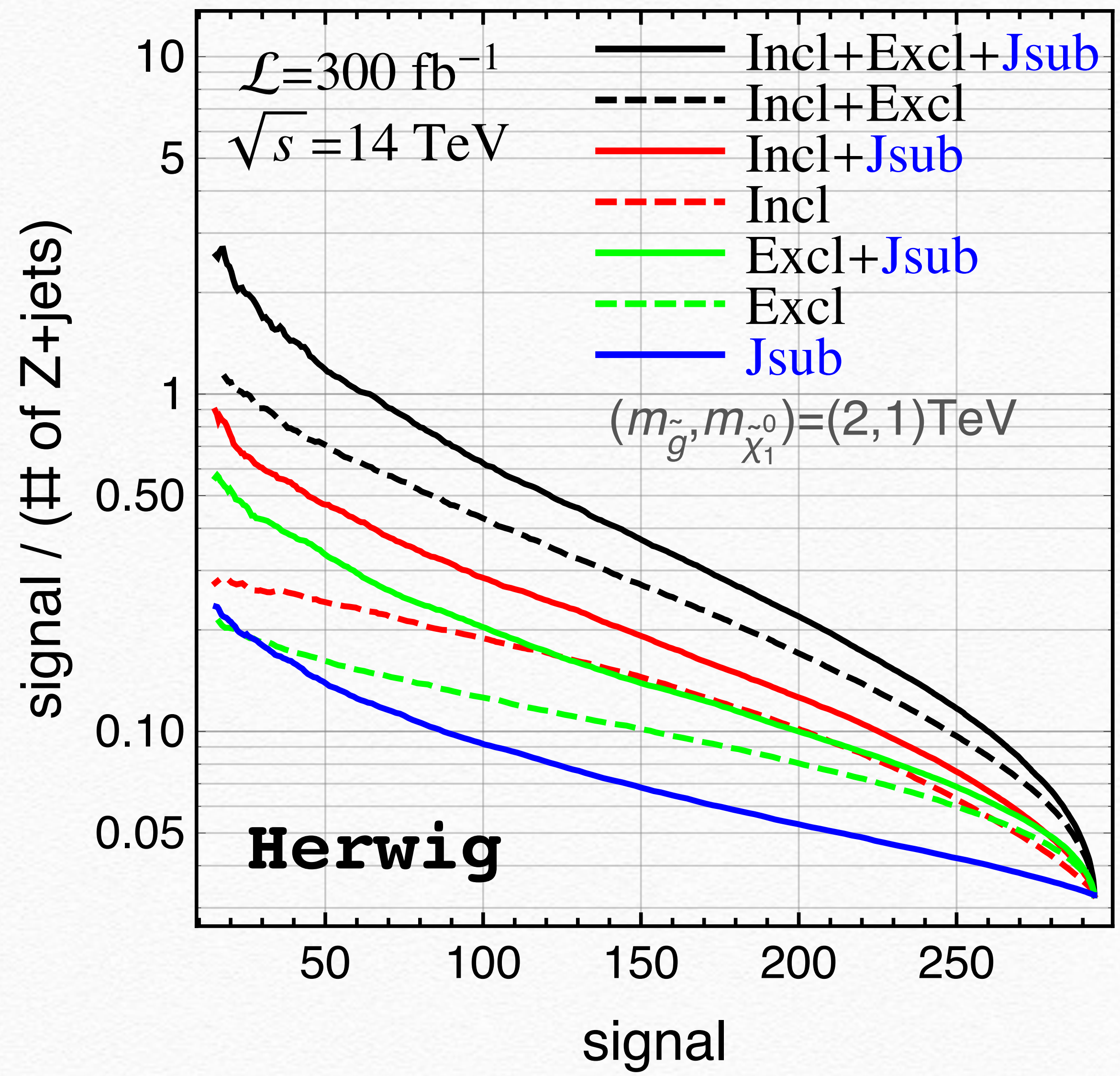
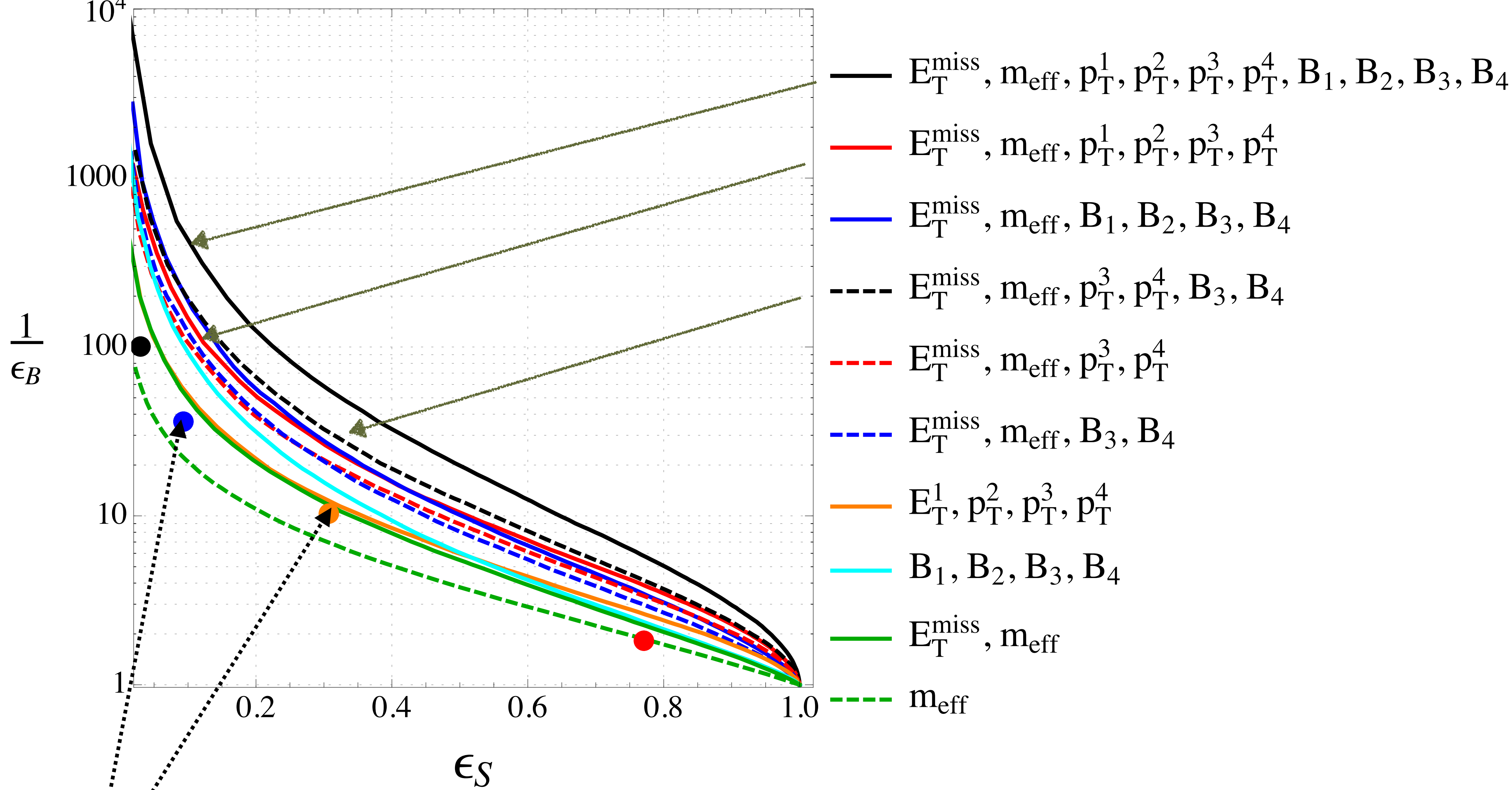


Fig. 2

list of discriminant



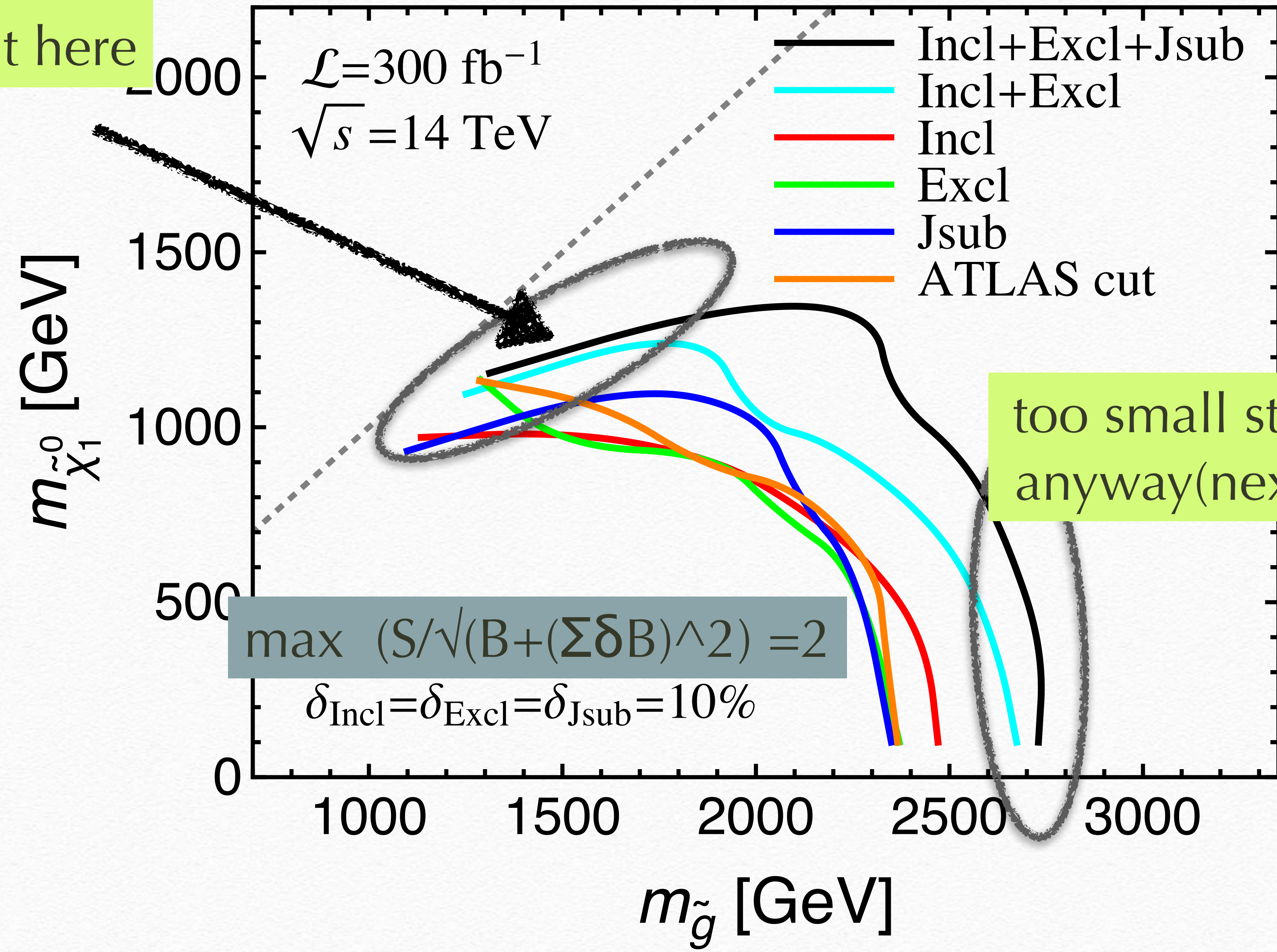
- $\frac{E_T^{miss}}{\sqrt{H_T}} > 10\ \mathrm{GeV}^{1/2}$
- $\frac{E_T^{miss}}{\sqrt{H_T}} > 10\ \mathrm{GeV}^{1/2}\ \ \&\ \ m_{eff} > 2.5\ \mathrm{TeV}$
- $\frac{E_T^{miss}}{\sqrt{H_T}} > 10\ \mathrm{GeV}^{1/2}\ \ \&\ \ m_{eff} > 3.0\ \mathrm{TeV}$
- $\frac{E_T^{miss}}{\sqrt{H_T}} > 10\ \mathrm{GeV}^{1/2}\ \ \&\ \ m_{eff} > 3.4\ \mathrm{TeV}$

using (pT3, B3) and (pT4, B4) give about same results using pT_i (i=1,4)

consistent with cut based results

not much
improvement
ISR is important here

contour of $\max_{BDT}$ $(S/\sqrt{(B+(\Sigma\delta B)^2)}) = 2$

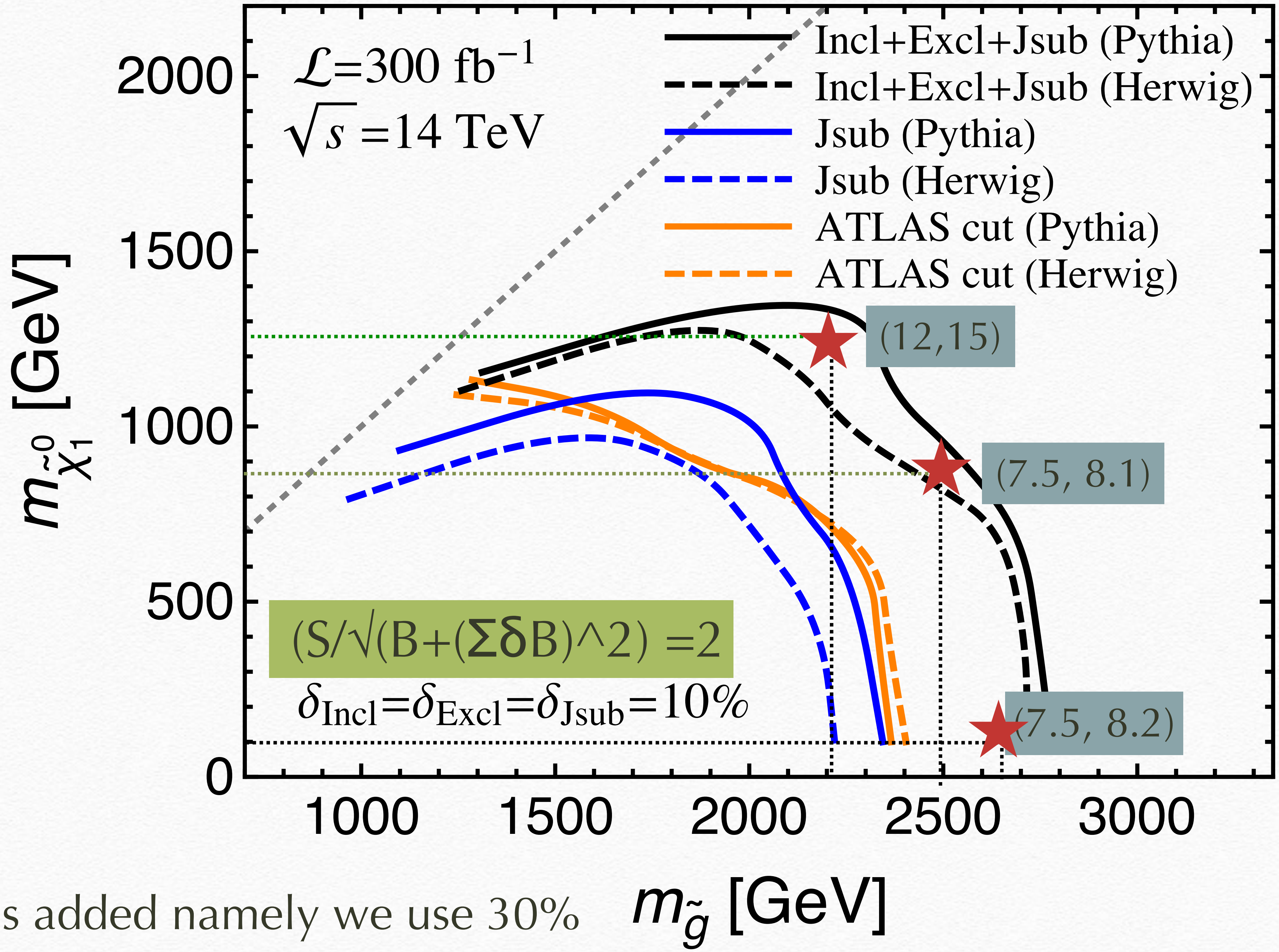


max $(S/\sqrt{(B+(\Sigma\delta B)^2)}) = 2$

too small statistics
anyway(next side)

generator dependence + statistics

contour of max$_{BDT}$ (S/√(B+(ΣδB)^2) =2



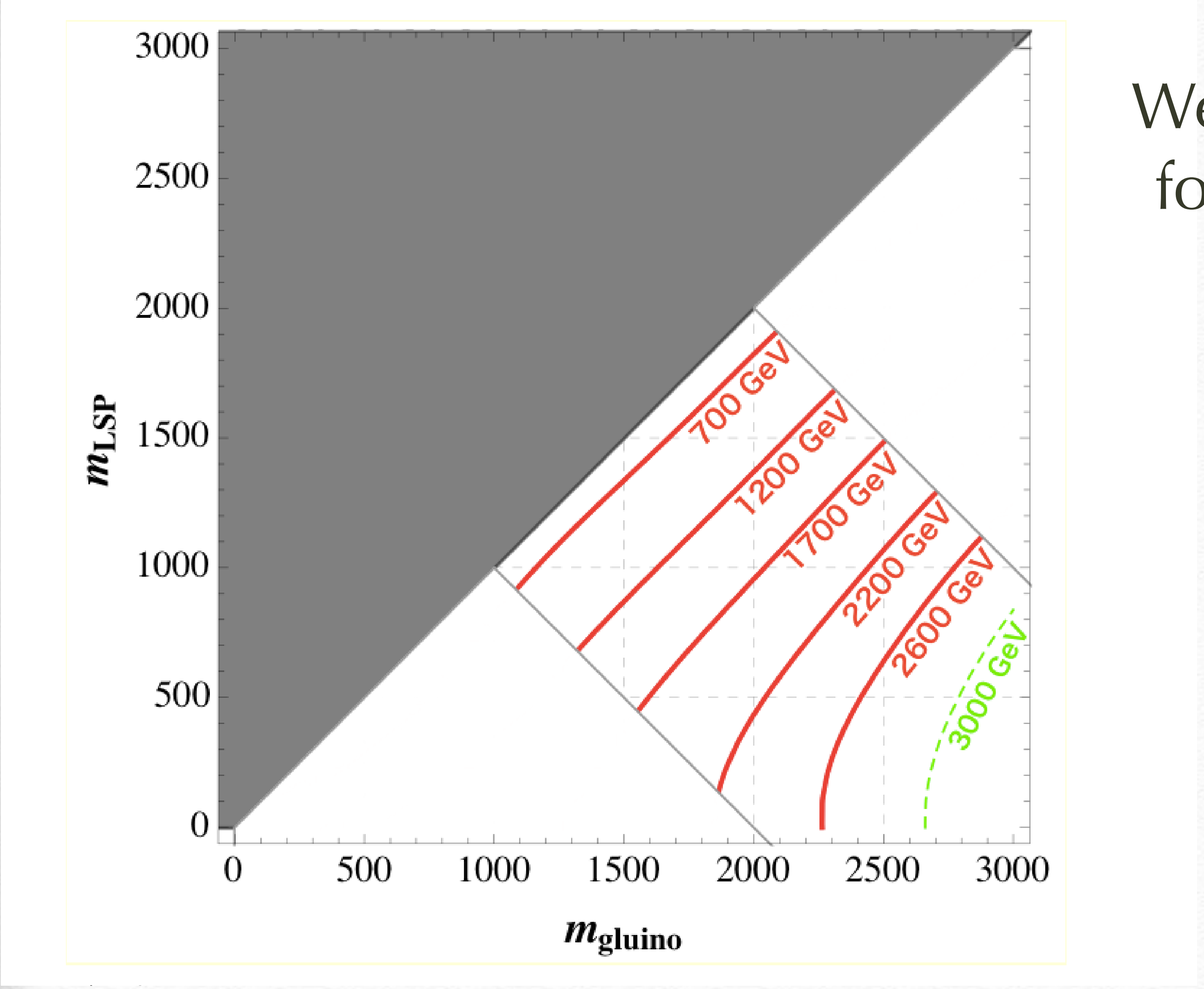
Systematics added namely we use 30%

conclusion

- Current excess: **Just wait**
- For future: we need systematic control NNLO, jet substructure (boost object, quark gluon separation)

Backups

M_{eff} cut



We apply different Meff cut for each parameter region